

The Effect of Sodium Bicarbonate Abrasives in Toothpaste on Dental Plaque Removal: A Pilot Study

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RESEARCH ARTICLE

Abstract

Background and Objective: The role of dental plaque as the etiology of caries and periodontal diseases has long been established. Therefore, plaque control is central to the prevention and management of these oral diseases. Among the different means of self-performed plaque control, brushing is the most essential. Moreover, toothpaste is a common adjunct during tooth brushing, as its abrasive contents are believed to enhance plaque removal. This study aimed to compare the effectiveness of plaque removal when brushing with a sodium bicarbonate abrasive-containing toothpaste, compared to brushing using an abrasive-free toothpaste.

Methods: Twelve students from the University of the Philippines College of Dentistry participated in the study. The subjects discontinued all oral hygiene measures for a minimum of 48 hours. Using the Modified Bass technique, they performed tooth brushing for two minutes, using either an abrasive-free or abrasive-containing toothpaste. Toothpaste allocation was randomized via fishbowl method. Pre-brushing and post-brushing plaque scores were recorded using the Turesky modification of Quigley-Hein plaque index. A washout period of 11 days was implemented before crossover to the second round, wherein employed toothpastes were switched. The difference in plaque reduction between the two kinds of toothpaste was analyzed using Wilcoxon signed rank test.

Results and Conclusion: Overall plaque reductions were 75% for the abrasive-free toothpaste and 73% for the abrasive-containing toothpaste. The difference between the toothpaste was statistically insignificant ($p=0.48$). Therefore, based on the study, brushing with a sodium bicarbonate abrasive-containing toothpaste resulted in similar levels of plaque removal, compared to brushing with an abrasive-free toothpaste. There is insufficient evidence that abrasives in toothpaste result in more effective dental plaque removal.

Keywords: *tooth brushing, toothpaste, abrasives, dental plaque*

Introduction

Periodontal disease and dental caries are the two most common oral diseases, and the etiologic role of dental plaque in the aforementioned conditions is well documented [1,2,3]. Dental plaque is a biofilm, which has been defined as “matrix-enclosed bacterial populations adherent to each other and/ or to surfaces or interfaces” [4]. In the oral cavity, when biofilms form on the grooves and smooth surfaces of the teeth, bacteria produce acids that may lead to the development of dental caries. On the other hand, biofilms that grow along the gingival margin and in the gingival sulcus contribute to the pathogenesis of periodontal diseases [5]. Various plaque control measures that aim to remove and prevent the accumulation of microbial deposits on the teeth

are, therefore, integral to the achievement and maintenance of good oral health. Among the measures that patients can perform to control plaque, thorough tooth brushing has been advocated as the most important [6].

When tooth brushing, individuals normally use toothpaste as an adjunct. Toothpastes are employed because they facilitate dental plaque removal, and serve as a vehicle for applying agents on the teeth [7]. It has been said that toothpastes offer several functions: protect against caries by means of fluoride [8], prevent plaque formation through antiplaque agents, such as, triclosan, control halitosis [9], reduce tooth sensitivity by means of desensitizing agents [10], lead to a sense of pleasant taste and coolness after brushing [11], and whiten and remove extrinsic stains from

teeth by means of abrasives [12]. Moreover, the addition of abrasives in toothpastes has been justified by the belief that such components increase the effectiveness of dental plaque removal [7].

Abrasives in commercial toothpastes may be classified into three major groups: carbonates, phosphates, and silicas [13]. Highly abrasive toothpastes may lead to dental abrasion during tooth brushing. Therefore, standards are in place to ensure that the addition of abrasives would enhance plaque removal without damaging tooth structure. The level of abrasiveness of toothpastes is expressed as a radioactive or Relative Dentin Abrasivity (RDA) value. The International Organization for Standardization (ISO) and the American Dental Association have set an upper limit of 250 RDA for toothpastes. Those with RDA of 151-250 are classified as highly abrasive. On the other hand, moderately and low abrasive toothpastes have 70-150 and <70 RDA, respectively [12]. Sodium bicarbonate, a type of carbonate abrasive, has been incorporated in commercial toothpastes for several decades already. Toothpastes with sodium bicarbonate are generally of low abrasivity. Pure sodium bicarbonate has an RDA of 7, while commercial toothpastes containing 10-67 % of the said abrasive have been found to have an RDA ranging from 35-134. Sodium bicarbonate-containing toothpaste, therefore, meet the standards for preventing tooth wear, when used as adjuncts during tooth brushing [14].

Although toothpaste abrasives are traditionally assumed to facilitate mechanical plaque removal, studies that have investigated the role of toothpastes on brushing effectiveness have yielded inconclusive results. In a study by Creeth *et al.* in 2009, no difference was found in the amount of plaque removed after tooth brushing, whether toothpaste was used or not [15]. Similar findings were noted by Parizotto *et al.* when they compared brushing with and without toothpaste, using children in the deciduous dentition phase as their subjects [16]. Still another research, this time by Zanatta *et al.*, reported no statistically significant differences in plaque removal, when brushing with toothpaste and with water were compared [11]. In contrast, several studies have concluded that more effective tooth brushing was achieved by subjects who performed the procedure without toothpaste. Binney *et al.*, in one of the earliest studies comparing tooth brushing with and without toothpaste, reported greater plaque removal when no toothpaste was employed [17]. Such results are corroborated by two researches by Paraskevas *et al.* in 2006 and 2007, both of which reported that tooth brushing without toothpaste

resulted in greater plaque reduction. The researchers concluded that toothpastes and the abrasive additives did not play a role in plaque removal [18, 19]. On the other hand, a research by Eid and Talic demonstrated more effective plaque removal when brushing with toothpaste compared to brushing with water [20]. The potential plaque removal efficacy of abrasives was also observed in a study by Putt *et al.* The investigators reported greater plaque removal with increasing levels of abrasiveness in different sodium bicarbonate-containing toothpastes [21].

In light of the equivocal results of previous researches, this study aimed to compare the effectiveness of dental plaque removal when brushing with a sodium bicarbonate abrasive-containing toothpaste, and using an abrasive-free toothpaste. At present, all commercially available toothpastes contain different abrasive agents with varying degrees of abrasiveness. Therefore, in this study, the two types of toothpastes were formulated and manufactured to ensure that the composition was the same, except for the presence or absence of sodium bicarbonate abrasives.

Methodology

Subjects

The study protocol was approved by the Research Ethics Board of the University of the Philippines Manila. The subjects were oriented about the nature of the study and the procedures that would be performed. They were given recruitment forms for signing prior to the screening process. Those who agreed and passed the screening process were reoriented about the study protocol and informed consent was obtained from the subjects prior to proceeding with the clinical trial phase.

Twelve Doctor of Dental Medicine students from the University of the Philippines Manila, College of Dentistry participated in the study. The subjects were enrolled as second-year proper students during the first semester of Academic Year 2013-2014 which was the time of implementation of the study. A sample size of 35 was computed based on the study of Paraskevas *et al.* in 2007 using Russ Lenth's power analysis. However, out of the 50 students from the target population, only 16 agreed to undergo the screening process. Thirteen students fulfilled the inclusion criteria, but only 12 completed the clinical trials.

The inclusion criteria were adapted from Creeth *et al.* [15], Paraskevas *et al.* [18], and Lie *et al.* [22] which included the

following: adults 18 years of age and above with at least 20 gradable teeth (excluding third molars), a bleeding on probing (BOP) percentage of $\leq 30\%$ using the BOP index by Ainamo and Bay [23], a minimum plaque score of 2.0 using the Turesky modification of Quigley-Hein plaque index [24], and no systemic illness. Exclusion criteria similar to the protocol of Paraskevas *et al.* [18] were adapted and included individuals who: have restricted free movement of hands or fingers, are wearing orthodontic bands or oral appliances, have periodontal disease, Class V and extensive interproximal dental caries, oral lesions or pathologies, have used antibiotics for the last six months, have been using mouthwash with plaque-reducing activities on a regular basis, have hypersensitivity to components of toothpastes, and are using medications that might affect the periodontal condition.

Toothpaste Production and Safety

The abrasive-free and abrasive-containing toothpastes were formulated and manufactured at the University of the Philippines College of Pharmacy (UPCP). Due to intellectual property rights concern, the UPCP only disclosed the components used, but not the formulation of the toothpastes. Both toothpastes contained distilled water, sodium lauryl sulfate, sodium monofluorophosphate, and sorbitol. The difference was that the abrasive-containing toothpaste included sodium bicarbonate (Figure 1). To ensure the safety and wellbeing of the participants, a certificate from the UPCP was issued stating that the Good Manufacturing Practice (GMP) was performed during the formulation of the toothpastes. According to the Pharmaceutical Inspection Convention, GMP is a set of guidelines or principles "which ensures that medicinal products are consistently produced and controlled to the quality standards appropriate to their intended use and as required by the marketing authorization or product specification." Good Manufacturing Practice is concerned with both production and quality control [25].

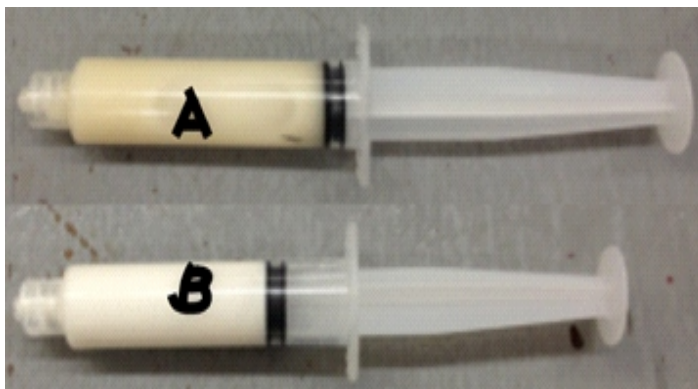


Figure 1. Abrasive-free (A) and abrasive-containing (B) toothpastes

Study Design

A double-blind, crossover design was employed. The study was conducted at the Oral Medicine Clinic of the College of Dentistry, University of the Philippines Manila.

The subjects who passed the screening process were instructed in a one-on-one manner on the Modified Bass technique, in order to standardize the manner of tooth brushing of all the subjects. They were given a manual toothbrush with medium, flat-trimmed nylon bristles to be taken home and used for a three-day familiarization period. During these days, the subjects were asked to perform the Modified Bass technique every time they brushed their teeth. After three days, the periodontal statuses of the subjects were reassessed to ensure a BOP index $\leq 30\%$ [22,23]. Periodontal probing was performed at all times using a University of North Carolina-15 probe. Tooth polishing was performed to achieve a zero-plaque baseline prior to dental plaque re-growth. The subjects were then asked to stop all oral hygiene measures for a minimum of 48 hours, to allow for plaque accumulation.

After dental plaque re-growth, the subjects returned to the Oral Medicine Clinic and were reinstructed on the Modified Bass technique of tooth brushing. Accurate return demonstration on a dental tooth model was required from each subject before he or she could proceed with the clinical trial. For the pre-brushing plaque assessment, the subjects were asked to swish with an erythrosine-containing disclosing solution for 30 seconds. Plaque scores were recorded on six sites per tooth using the Turesky modification of Quigley and Hein plaque index [24]. This index scores stained plaque based on the following criteria: 0 - no plaque, 1 - separate flecks of plaque at the cervical margin of the tooth, 2 - a thin continuous band of plaque ≤ 1 mm at the cervical margin of the tooth, 3 - a band of plaque wider than 1 mm but covering less than one-third of the crown of the tooth, 4 - plaque covering at least one-third but less than two-thirds of the crown of the tooth, and 5 - plaque covering two-thirds or more of the crown of the tooth (Figure 2).

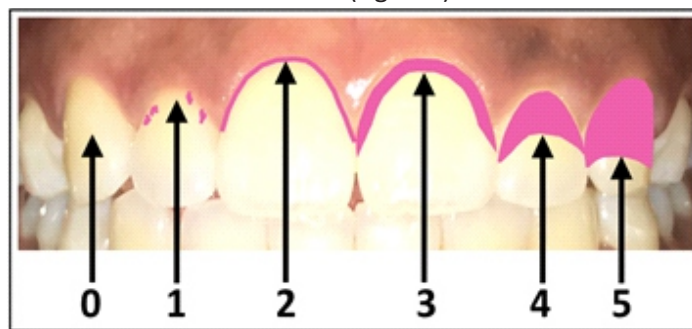


Figure 2. Turesky *et al.* modification of Quigley & Hein plaque index

Using the Modified Bass technique, the subjects then performed tooth brushing for two minutes, with either an abrasive-containing or abrasive-free toothpaste. Toothpaste allocation was randomized via fishbowl method. Each subject was asked to brush under the supervision of one researcher, using the assigned toothpaste. A total of 20 seconds was allotted for each sextant of the mouth, with 10 seconds each spent for the buccal and the lingual tooth surfaces. With the aid of a timer, the researcher signaled each subject when to move on to another sextant. The participants used the same toothbrushes that were provided to them during the familiarization period.

After brushing, the subjects were asked to rinse thoroughly with water, followed by a 30-second swishing of the erythrosine-containing disclosing solution. Post-brushing plaque assessment was done and the results were recorded. Tooth polishing was then performed to ensure that any remaining plaque left after brushing was removed. The subjects were dismissed and a washout period of 11 days was implemented before continuing with the second round of the clinical trial wherein the same protocol was followed but with switching of the employed toothpaste. During the washout period, the subjects were instructed to continue using the Modified Bass technique of tooth brushing.

In all cases, a single calibrated examiner who was blinded to the toothpaste used by the subjects, performed periodontal probing to determine the BOP index, as well as determine the pre-brushing and post-brushing plaque scores. A different researcher supervised tooth brushing, performed randomization, and dispensed the toothpastes to ensure concealment from both the subjects and the examiner.

Data Analysis

The difference between pre-brushing and post-brushing plaque indices was expressed as the percentage of plaque

reduction ($100 \times \frac{\text{pre-brush} - \text{post-brush}}{\text{pre-brush}}$), similar to the formula used by Paraskevas *et al.* and Jayakumar *et al.* [18,26].

SPSS software was used for statistical analysis. The difference in dental plaque reduction between tooth brushing with abrasive-containing and abrasive-free toothpastes was computed using Wilcoxon signed rank test. Values of $p \leq 0.05$ were used to indicate the significant difference.

Results

Twelve subjects completed the clinical trial. Two males and 10 females participated, and the ages of the subjects ranged from 19-21 years (mean \pm SD = 19.58 \pm 0.67).

The pre-brushing and post-brushing plaque indices when using the sodium bicarbonate abrasive-containing and abrasive-free toothpaste are presented in Table 1. A comparison of pre-brushing plaque scores between toothpaste groups revealed no significant difference, regardless of the examined surface ($p > 0.05$). Analysis showed that after two minutes of supervised tooth brushing using the Modified Bass technique, the mean plaque reductions when using either of the two toothpastes were statistically significant for all of the surfaces examined.

When considering both the buccal and lingual surfaces of the teeth, brushing with an abrasive-containing toothpaste resulted in a mean plaque reduction of 73%. When only the buccal surfaces were accounted for, the mean plaque reduction was 80%, whereas for the lingual areas only, there was a 64% mean plaque reduction (Figure 3).

On the other hand, brushing with an abrasive-free toothpaste resulted in a mean plaque reduction of 75% when scores on both the buccal and lingual surfaces were pooled together. When only the buccal surfaces were considered, a mean plaque reduction of 81% was observed, whereas when

Table 1. Pre-brushing and post-brushing plaque scores (Turesky *et al.* modification of Quigley and Hein plaque index) using abrasive-containing and abrasive-free toothpastes.

Tooth Surface Examined	Abrasive-containing Toothpaste (Mean \pm SD)	Abrasive-free Toothpaste (Mean \pm SD)
Buccal and Lingual Pre-brushing Post-brushing	3.09 \pm 0.53 0.81 \pm 0.21	3.22 \pm 0.43 0.81 \pm 0.28
Buccal Pre-brushing Post-brushing	3.74 \pm 0.60 0.72 \pm 0.35	3.81 \pm 0.54 0.72 \pm 0.40
Lingual Pre-brushing Post-brushing	2.44 \pm 0.54 0.89 \pm 0.27	2.62 \pm 0.46 0.90 \pm 0.26

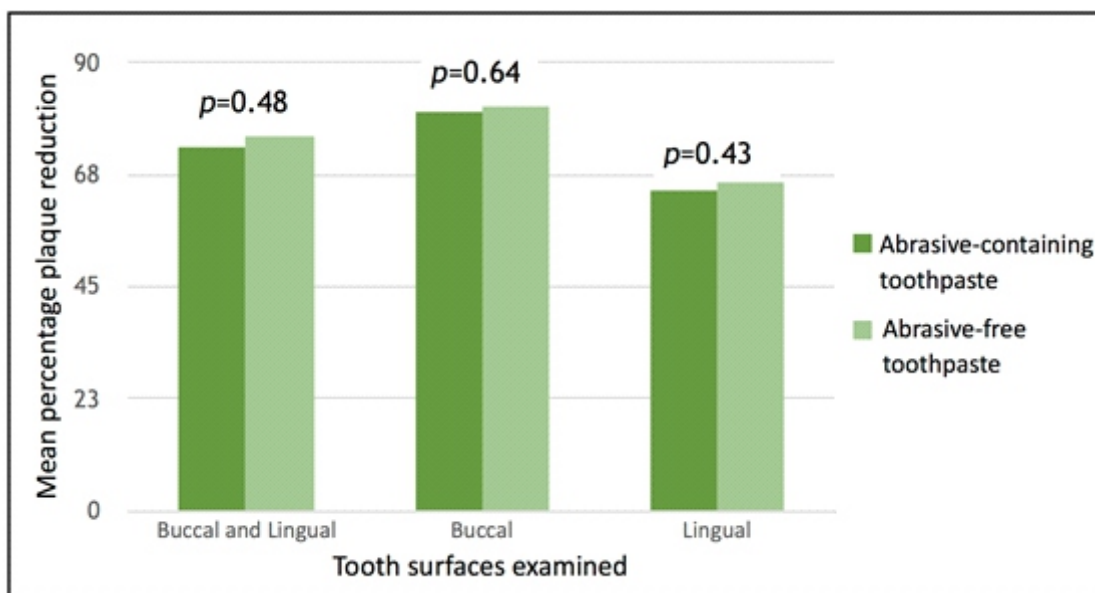


Figure 3. Mean plaque reductions with the use of abrasive-containing and abrasive-free toothpastes according to tooth surfaces examined. Intergroup comparison yielded statistically insignificant differences ($p > 0.05$) regardless of the surface examined.

only the lingual areas were accounted for, there was a 66% mean plaque reduction (Figure 3).

However, when the percentage of plaque reductions between groups were compared, the analysis showed that the differences were not statistically significant for all the surfaces examined ($p = 0.48$ for the buccal and lingual surfaces, $p = 0.64$ for the buccal surfaces only, and $p = 0.43$ for the lingual surfaces only). The data gathered show that regardless of the surfaces examined, tooth brushing with abrasive-free and abrasive-containing toothpastes are both capable of removing plaque. However, following the statistical analyses of the data, the results show that the addition of sodium bicarbonate as an abrasive in toothpaste did not improve the plaque removal effectiveness of the toothpaste.

Discussion

The results of this study showed that sodium bicarbonate as a toothpaste abrasive did not increase the effectiveness of dental plaque removal. No statistically significant difference in percentage plaque reduction was noted, when comparing tooth brushing using an abrasive-free and an abrasive-containing toothpaste.

The present study is double-blinded, with both the participants and examiner unaware of the group allocation. This investigation sought to reduce or eliminate brushing performance bias that may arise when a subject is aware of the intervention or group that they belong to. Therefore, since

commercial toothpastes without abrasives are not available in the local Philippine market, abrasive-free and abrasive-containing toothpastes were formulated and manufactured at the University of the Philippines College of Pharmacy, for use in the clinical trial. By comparing an abrasive-free with an abrasive-containing toothpaste, this study was able to focus on the particular effect of sodium bicarbonate abrasives on dental plaque removal.

Similar results have been described by Creeth *et al.* in 2009. In their research, Creeth *et al.* recorded the same amount of plaque removal following tooth brushing with and without the adjunctive use of toothpaste. The researchers, therefore, concluded that “plaque removal was not influenced by the presence of toothpaste, indicating that toothpaste constituents, such as abrasives and surfactants, do not meaningfully assist the action of the toothbrush” [15]. However, while this study and that of Creeth *et al.* both yielded no significant difference in plaque removal, the results of both studies are not directly comparable. Creeth *et al.* required their subjects to brush for only 1 minute. On the other hand, this study employed a brushing time of two minutes. According to literature, after two minutes, an optimum in plaque-removing efficacy was reached when using both manual and power-driven toothbrushes. Brushing for a minimum of 2 minutes or longer is therefore recommended, regardless of the type of toothbrush used [27, 28]. In addition, the present study differs in that the subjects were instructed on the Modified Bass technique of tooth brushing. This was done in order to standardize the manner of plaque removal, and, therefore eliminate the variability that

otherwise would have come with performance of different brushing techniques. In the study of Creeth *et al.*, no attempt was made to modify the subjects' brushing styles, and the subjects were asked to brush with their usual technique.

Zanatta *et al.* also studied the difference in dental plaque removal when brushing without, and with toothpaste. The researchers, likewise did not find any statistically significant differences between groups in terms of pre-brushing and post-brushing plaque indices. Moreover, similar to this study, Zanatta *et al.* reported no difference between groups when separate analyses were done on the buccal and on the lingual surfaces of the teeth [11]. The research of Zanatta *et al.* differs in that a split-mouth design was employed as opposed to a crossover design in the present study. Both experimental designs have the advantage of allowing each participant to serve as his/her own control. However, in split mouth designs, there is potential bias due to carry-across effects. Such effects may confound treatment efficacy estimates [29]. In this study, a washout period of 11 days was instituted in order to avoid a possible carryover effect. A washout period of at least 72 hours was employed by Creeth *et al.* [15], while in the studies of Paraskevas *et al.* and Jayakumar *et al.*, washout periods were one week [18, 26].

In a study by Parizzotto *et al.* in 2003, similar findings of no significant difference in plaque removal between tooth brushing with and without toothpaste were reported. The researchers used a parallel design and randomly assigned 8 children to each group. However, the subjects were only 4-6 years old and they were instructed to brush their own teeth [16]. According to the Policy Statement of the American Academy of Pediatrics, "parents or caregivers should help/supervise a child brushing his or her teeth until mastery is obtained, usually at around 8 years of age" [30].

In contrast to the present study, Eid and Talic compared plaque removal between the use of toothpaste or water when brushing teeth. After one minute of professional tooth brushing, greater plaque removal was noted in subjects whose teeth were cleaned using toothpaste, wherein overall reduction in plaque was 67%. For those subjects who received brushing with water, a reduction of only 59% was recorded [20]. Moreover, in a study by Putt *et al.* comparing different abrasive-containing toothpastes, a positive correlation was observed between sodium bicarbonate abrasive concentration and plaque removal efficacy. However, the results of this study cannot be directly compared to the aforementioned researches because of key

differences in methodology. Most notably, Putt and his co-researchers compared sodium bicarbonate-containing toothpastes with others containing different abrasive agents. No comparison was made to brushing with an abrasive-free toothpaste, nor to brushing with water [21].

Other studies that have looked into the effect of toothpaste abrasives on dental plaque removal have reported statistically significantly greater plaque removal when brushing without the use of toothpaste. In a study conducted by Paraskevas *et al.* in 2007, subjects who brushed without toothpaste removed 6% more dental plaque as compared to those who brushed their teeth with the adjunctive use of toothpaste [18]. Similarly, Jayakumar *et al.* concluded that the use of toothpaste did not enhance dental plaque removal and to the contrary, may decrease the brushing effect [26].

One other research that was able to look into the effects of abrasives was conducted by Paraskevas *et al.* in 2006. In their crossover study, the researchers compared three toothpastes, all containing hydrated silica but with varying degrees of abrasiveness. Based on the results, the degree of abrasiveness had no effect on dental plaque removal, as all three toothpastes resulted in the same reduction of plaque following tooth brushing. Moreover, a fourth group that performed brushing without toothpaste removed significantly more plaque than brushing with any of the three toothpastes with hydrated silica as abrasive [19]. The contradicting results of these earlier studies to those of this research may be due to differences in experimental design. In particular, there was lack of blinding of subjects in the three previous investigations.

The findings of this research should be interpreted in the context of some limitations. First, the sample size of 12 per group may be insufficient to allow extension of study results to the general population. Another limitation may be that our study group consisted of dental students. Given the motivation and knowledge level in oral hygiene of the students, the choice of participants may be ideal in terms of adherence to the study protocol, particularly with regard to tooth brushing performance. However, the study group may not be representative of the general population, and, therefore, the results may only be unique to the study participants.

Conclusion

Regardless of the surfaces examined, the difference in dental plaque reduction between the abrasive-free and abrasive-containing toothpastes was statistically insignificant ($p>0.05$). Based on the study, the addition of sodium

bicarbonate as abrasives in toothpaste resulted in similar levels of dental plaque removal, compared to an abrasive-free toothpaste. There is insufficient evidence that abrasives in toothpaste result in more effective plaque removal. Future studies with a greater number of participants from different backgrounds are recommended to validate the results of the study. Also, given the above-mentioned results, the researchers would still recommend brushing with toothpaste since it provides other benefits, such as caries prevention, tooth desensitization, and freshening of the mouth.

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Conflict of Interest

The authors declare that they have no conflicts of interest. Furthermore, this research did not receive any grant from any funding agency.

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